McGinn & Gibb, PLLC

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Patents, Trademarks, Copyrights, and Intellectual Property Law
8321 Old Courthouse Road, Suite 200
Vienna, Virginia 22182-3817
Telephone (703) 761-4100
Facsimile (703) 761-2375; (703) 761-2376

APPLICATION
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APPLICANT:	Tomohiro SAKAI
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METHOD AND SYSTEM FOR ANALYZING LOOP INTERFACE FAILURE

BACKGROUND OF THE INVENTION

1. Field of the Invention

5   The present invention relates to a method for

analyzing loop interface failures and a system having a

function of analyzing loop interface failures.

2. Description of the Related Art

Recently, an interface which connects devices in a

10   loop such as a Fibre Channel Arbitrated Loop (FC-AL) has

been widely used in disk array apparatuses and the like,

since it has a simple connecting configuration of cables

and can easily accommodate device extensions. However,

this type of interface has such a problem that, when

15   signals cannot propagate in the loop because of failures or

the like in interface circuits of connected devices (this

is called, for example, loop abnormality or link down), the

whole loop cannot be used. That is, even though a failure

occurs in only one device, all devices connected to the

20   loop cannot be used. In order to cope with this problem,

disk array apparatuses usually have interface circuits for

two ports, so that these devices are connected to two

independent loops. With this configuration, even when one

loop of the dual loop interfaces is out of use because of a

25   failure or the like, accesses can be performed using the

other loop, to thereby improve reliability. Further, this kind of disk array apparatus has a function of identifying a faulty device and restoring the failure when a loop abnormality occurs.

5   As an example, the Japanese Patent Application Laid-open No. 2002-7077 discloses a disk array apparatus having two FC-ALs, or loops A and B. In this example, when an abnormality occurs in the loop A, a disk controller in the loop A stops the normal disk processing and transits to a

10   temporary degenerate state, and the loop B acts the processing for the loop A. The disk controller in the loop A performs a diagnosis of the loop A by itself and bypasses the faulty device from the loop A to thereby clear the temporary degenerate state of the loop A. With this

15   structure, it is possible to identify a faulty component while keeping response to the host, when a loop abnormality occurs. However, in the aforementioned example, a loop abnormality is supposed to be an intermittent failure. Therefore, it is assumed that the loop A is not abnormal at

20   the time of diagnosing the loop A.

       As another example, the Japanese Patent Application Laid-open No. 2001-216206 discloses a method for analyzing failures, which is applicable to disk array apparatuses having two FC-ALs, or loops A and B, in which an enclosure

25   service device directly connects to each loop. An

enclosure service device is a device for monitoring the environment inside of the casing and managing resources of a device which conforms to the ANSI Standard (NCITS 305-199X). The device also has a function of controlling a

5   loop connection switching unit which performs bypassing or releasing the bypass of disks connecting to the loop, to which the device itself connects. The enclosure service device directly connecting to the loop acts as a device connecting to the loop interface as same as the disk

10   connecting to the loop. Therefore, when a unique failure occurs in the loop to which the enclosure service device connects, the disk controller of the loop cannot instructs the enclosure service device through the loop. In order to cope with this problem, in the aforementioned example, an

15   interface is provided between the enclosure service devices connecting to respective loops. The interface works in such a manner that when a failure occurs in the loop A, it instructs the enclosure service device in the loop A to bypass or release the bypass of disks in the loop A, via

20   the enclosure service device in the loop B, for diagnosing the loop A.

As described above, in the system of disk array apparatus having a loop interface such as an FC-AL, the reliability is improved by using dual loop interfaces and

25   bypassing faulty components through an immediate failure

analysis at the time of loop abnormality. However, in the
system in which enclosure service devices directly connect
to respective loops, some other problems arise as described
below, when loop failures occur in the both loops of the

5   dual loop interfaces at the same time.

A first problem is that the devices connecting to the
loop interfaces cannot be detached from or reconnected to
the loops at all, since the enclosure service devices for
controlling the loop connection switching units, which

10   actually perform detachment and reconnection, cannot be
accessed from either loop.

A second problem is that a loop diagnosis for
identifying faulty devices, which cause the loop
abnormalities, cannot be performed. In order to perform

15   the loop diagnosis, the devices connecting to the loop
interfaces must be detached from and reconnected to the
loops. However, the detachment and the reconnection cannot
be performed in the system.

A third problem is that the system remains

20   completely stopped, since the loop diagnosis cannot be
performed so that faulty components cannot be removed from
the loops.

SUMMARY OF THE INVENTION

25   The present invention is proposed considering these

problems. An object of the present invention is, in a system of a disk array apparatus or the like having multiplexed loop interfaces in which controlling devices such as enclosure service devices connect to respective

5　loops, to perform detachment and reconnection of devices connecting to the loop interfaces, and to perform loop diagnoses so as to identify faulty devices causing loop abnormalities, to thereby prevent the system from being completely stopped, even when abnormalities occur in all

10　loops.

A method for analyzing loop interface failures according to the present invention is for a system of a disk array apparatus or the like, which includes multiplexed loop interfaces such as FC-Als. In such a

15　system, controlling devices such as enclosure service devices, for controlling loop connection switching means which connect/detach devices such as hard disk devices to/from the respective loop interfaces, connect to the respective loop interfaces, and interfaces are provided so

20　that the controlling devices can communicate each other. When the controlling devices detect that abnormalities occur in all loop interfaces, the controlling devices control the loop connection switching means so as to detach all devices connecting to at least one of the loop

25　interfaces.

It should be noted that the controlling devices may
be configured in the following manner. That is, when
detecting that commands such as heartbeat commands have
ceased, which commands are transmitted at a regular

5   interval through the loop interfaces to which the
controlling devices themselves connect, the controlling
devices inform to other controlling devices through the
interfaces that the commands have ceased, and when all
controlling devices detect that the commands have ceased,

10   they detect that abnormalities occur in all loop interfaces.
Further, in the method, loop diagnoses for identifying
faulty devices may be performed by accessing to a
controlling device connecting to another loop interface,
via the controlling device connecting to the loop interface

15   in which all connected devices were detached and the loop
abnormality has been resolved. Further, when abnormalities
occur in all loop interfaces, a controller, connecting to
the devices and to the controlling device through one loop
interface of the multiplexed loop interfaces, may judge

20   whether the loop abnormality of the loop interface to which
it connects is resolved within a certain period of time,
and when the loop abnormality was resolved within the
certain period of time, inquire the controlling device
whether it detached all devices. If all devices were

25   detached by the controlling device, countermeasure

processing against a double-loop link failure may be performed, which includes the loop diagnosis by a loop diagnostic means. Further, the devices determined as faulty in the loop diagnosis may be detached from the loop

5   interface so that the loop interface can be in use again. Further, the loop diagnosis for identifying faulty devices may be performed by accessing to a controlling device connecting to another loop interface, via the controlling device connecting to the loop interface which is in use

10   again.

A system having a function of analyzing loop interface failures according to the present invention is a system of a disk array apparatus or the like, and comprises, multiplexed loop interfaces such as FC-Als, and controlling

15   devices such as enclosure service devices having functions of controlling loop connection switching means for connecting/detaching devices such as hard disk devices to/from the respective loop interfaces. The controlling devices include, interfaces for communicating each other,

20   and means for controlling the loop connection switching means when detecting abnormalities in all loop interfaces, so as to detach all devices connecting to at least one of the loop interfaces.

It should be noted that the controlling device may

25   include means for detecting that commands such as heartbeat

commands have ceased, which commands are transmitted at a regular interval through the loop interface to which the controlling device itself connects, and informing to other controlling devices through the interfaces that the

5 commands have ceased, and when all controlling devices detect that the commands have ceased, they detect that abnormalities occur in all loop interfaces. Further, the system may include loop diagnostic means for performing loop diagnoses to identify faulty devices by accessing to a

10 controlling device connecting to another loop interface, via the controlling device connecting to the loop interface in which all connected devices were detached and the loop abnormality has been resolved.

Further, the system may include a controller

15 connecting to the devices and to the controlling device through one loop interface of the multiplexed loop interfaces. The controller may, when loop abnormalities occur in all loop interfaces, judge whether the loop abnormality in the loop interface to which it connects is

20 resolved within a certain period of time, and when the loop abnormality was resolved within the certain period of time, inquire the controlling device whether it detached all devices, and when all devices were detached by the controlling device, perform countermeasure processing

25 against a double-route link failure including a loop

diagnosis by a loop diagnostic means.

The loop diagnostic means may detach the devices determined as faulty in the loop diagnoses from the loop interface so that the loop interface can be in use again.

5 Further, the loop diagnostic means may perform the loop diagnoses for identifying faulty devices by accessing to a controlling device connecting to another loop interface, via the controlling device connecting to the loop interface which is in use again.

10 The enclosure service device of the present invention connects to one loop interface of the multiplexed loop interfaces such as FC-Als and has a function of controlling a loop connection switching means for connecting/detaching devices such as hard disk devices to/from the loop

15 interfaces. The enclosure service device includes an interface for communicating with another enclosure service device each other and a means for controlling the loop connection switching means when abnormalities occur in all loop interfaces so as to detach all devices connecting to

20 the loop interface.

It should be noted that the enclosure service device of the present invention may include means for detecting that commands have ceased, which commands are transmitted at a regular interval through the loop interface to which

25 the device itself connects, and informing to other

enclosure service devices through the interfaces that the commands have ceased, and when all enclosure service devices detect that the commands have ceased, the enclosure service devices detect that abnormalities occur in all of

5   the loop interfaces.

The controller of the present invention is a controller such as a disk controller or the like which, through one loop interface of the multiplexed loop interfaces such as FC-Als, connects to one or more devices

10   such as hard disk devices and to a controlling device such as an enclosure service device having a function of controlling a loop connection switching means for connecting/detaching the devices to/from the loop interface. The controller includes, a means for confirming that all

15   devices connecting to at least one of the loop interfaces have been detached by the controlling device which detected that abnormalities occurred in all of the multiplexed loop interfaces, and a loop diagnostic means for performing a loop diagnosis to identify a faulty device by accessing to

20   a controlling device connecting to another loop interface through the interface connecting the controlling devices so as to communicate each other, via the controlling device connecting to the loop interface in which all devices were detached and the loop abnormality has been resolved.

25   The loop diagnostic means of the controller according

to the present invention may detach the devices determined
as faulty in the loop diagnosis from the loop interface so
that the loop interface can be in use again. Further, the
loop diagnostic means may perform the loop diagnosis for
5   identifying faulty devices by accessing to a controlling
device connecting to another loop interface, via the
controlling device connecting to the loop interface which
is in use again.

10 (Operation)

In the present invention, it is detected in the
controlling devices connecting to respective loop
interfaces that abnormalities occur in all of the
multiplexed loop interfaces. The controlling devices, upon
15 detection, voluntarily control the loop connection
switching means to thereby detach all devices connecting to
at least one loop interface. Consequently, if the cause of
the loop failure is a fault of any device, the loop
abnormality of the loop interface, from which all devices
20 were detached, is resolved and the controlling device
connecting to the loop interface can be accessed. Since
the controlling devices can communicate each other through
interfaces, it is possible to access other controlling
devices via controlling devices which have been able to be
25 accessed. Therefore, devices connecting to any loop

interface can be detached and reconnected. Accordingly, it is possible to perform loop diagnoses for identifying faulty devices causing loop abnormalities, and by detaching the faulty devices, it is also possible to continue

5   operation of the system.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram showing an example of a disk array apparatus to which the present invention is

10   applied;

Fig. 2 is a block diagram showing an example of the inner structure of an enclosure service unit according to a disk array apparatus to which the present invention is applied;

15   Fig. 3 is a block diagram showing an example of the inner structure of a disk controller according to a disk array apparatus to which the present invention is applied;

Fig. 4 is a flowchart showing an example of a process when a disk controller of a disk array apparatus detects a

20   loop abnormality;

Fig. 5 is a flowchart showing another example of a process when a disk controller of a disk array apparatus detects a loop abnormality;

Fig. 6 is a flowchart showing an example of a

25   countermeasure processing against a single-route link

failure;

Fig. 7 is a diagram showing a state of a disk array apparatus in which a faulty disk is detached and only normal disks are connected;

5   Fig. 8 is a flowchart showing an example of countermeasure processing against a double-route link failure;

Fig. 9 is a block diagram showing another example of a disk array apparatus to which the present invention is

10   applied; and

Fig. 10 is a block diagram showing still another example of a disk array apparatus to which the present invention is applied.

15   PREFERRED EMBODIMENT OF THE INVENTION

Next, a preferred embodiment will be explained in detail with reference to the accompanying drawings.

(Structure)

20   Referring to Fig. 1, a disk array apparatus 1 according to an embodiment of the present invention connects to hosts A 91 and B 91 via host interfaces A 121 and B 121. The disk array apparatus comprises a disk unit device 5, a cash unit 6, a disk controller A 71, a disk

25   controller B 72, a host controller A 81, and a host

controller B 82.

The host controllers A 81 and B 82 perform host services such as command reception, data transfer, status response between the disk array apparatus and the hosts A

5 91 and B 92, respectively. The host controllers A 81 and B 82 connect to the cash unit 6 and to disk controllers A 71 and B 72 through an inner bus 110, so as to perform data transmission/reception each other. The host controllers A 81 and B 82 and the disk controllers A 71 and B 72 perform

10 requests for processing such as disk processing to other controllers, and status information of controllers such as information of loop analysis result, via a communicating means between controllers 100,.

The disk unit device 5 includes: a plurality of FC-AL

15 disks 21 to 2N, each of which has two FC-AL interface ports; loop connection switching units A 31 and B 32; and enclosure service units A 51 and B 52.

The loop connection switching units A 31 and B 32 are circuits, by which the FC-AL disks 21 to 2N are detached

20 from (hereinafter referred to as bypassed) or reconnected to (hereinafter referred to as released from bypass) the FC-ALs A 41 and B 42.

The enclosure service units A 51 and B 52 connect to the disk controllers A 71 and B 72 via the FC-ALs A 41 and

25 B42. The enclosure service units A 51 and B 52 have an

interface 130 for communicating each other. The enclosure
service units A 51 and B 52 are devices for monitoring the
inner circumstances and managing the inner resources of
devices defined by the ANSI Standard (NCITS 305-199X), and
5   include heartbeat monitors A 511 and B 521, heartbeat
receivers A 512 and B 522, and loop connection controllers
A 513 and B 523.

The loop connection controllers A 513 and B 523 have
functions of controlling the loop connection switching
10   units A 31 and B 32 so as to bypass or release the bypass
of the FC-AL disks 21 to 2N.

The heartbeat receivers A 512 and B 522 have
functions of receiving commands transmitted at an interval
of a certain period of time from the disk controllers A 71
15   and B 72 through the FC-ALs A 41 and B 42. The commands
transmitted from the disk controllers A 71 and B 72 at an
interval of a certain period of time are called heartbeat
commands hereinafter. The heartbeat commands may be
commands defined as dedicated commands or well-known
20   commands (for example, Receive Diagnostic Results command).

The heartbeat monitors A 511 and B 521 monitor
receiving conditions of the heartbeat commands at the
heartbeat receivers A 512 and B 522, which are in the
enclosure service units A 51 and B 52 in which the
25   heartbeat monitors A 511 and B 521 are included,

respectively. The heartbeat monitors A 511 and B 521, when detecting that reception of the heartbeat commands have ceased in the heartbeat receivers A 512 and B 522, inform the state to the other heartbeat monitors B 521 and A 511,

5   respectively, through the interface 130. The heartbeat monitors A 511 and B 521 have functions of, when detecting that receptions of the heartbeat commands have ceased in both heartbeat receivers A 512 and B 522, bypassing all FC-AL disks 21 to 2N from the FC-ALs A 41 and B 42 by the loop

10   connection controllers A 513 and B 523. The enclosure service units A 51 and B 52 have functions of, in the case that the receptions of commands have ceased and all disks have been bypassed, recording the state inside and reporting that bypass has been performed responding to

15   inquiries from the disk controllers A 71 and B 72. The reporting function to inquiries may be realized as, for example, a responding function to the Receive Diagnostic Results commands.

Fig. 2 shows an example of the inner structure of the

20   enclosure service unit A 51. Since the enclosure service unit B 52 has the same structure, only the enclosure service unit A 51 is explained in Fig. 2. The enclosure service unit A 51 shown in Fig. 2 includes a CPU 531, an interface chip 533 connecting to a bus 532 of the CPU 531,

25   a memory 534, a communication unit 535, and a switching

unit 536. The interface chip 533 is a portion of the

interface between the enclosure service unit A 51 and the

FC-AL A 41. The communication unit 535 is a device for

communicating each other with the enclosure service unit B

5   52 via the interface 130. The switching unit 536 is formed

of, for example, a register for retaining control signals

for the loop connection switching unit A 31 and the like.

The memory 534 is formed of ROM and RAM, and has an area

for storing programs for the enclosure service device

10   (including firmware) as well as storing status information

showing the status of the own device and each device

connected to the FC-AL A 41, and the like. The CPU 531

executes the programs for the enclosure service device

stored in the memory 534 to thereby control the whole

15   device and realize functions necessary for the device.

        Referring to Fig. 1 again, the disk controller A 71

forms the FC-AL A 41 between only one port in each of the

FC-AL disks 21 to 2N, and the other disk controller B 72

forms the FC-AL B 42 between the other port in each of the

20   FC-AL disks 21 to 2N. The disk controllers A 71 and B 72

perform various disk processing such as reading from and

writing to the FC-AL disks 21 to 2N with instructions from

the host controllers A 71 and B 82, or by their own

determinations of the disk controllers A 71 and B 72.

25   Further, the disk controllers A 71 and B 72 also instruct

the enclosure service units A 51 and B 52 to bypass or
release the bypass of the FC-AL disks 21 to 2N, and read
information of bypass state and the like from the enclosure
service units A 51 and B 52. Further, the disk controllers

5   A 71 and B 72 include temporary degeneracy controllers A
710 and B 720, loop diagnostic units A 711 and B 721, and
heartbeat transmitters A 712 and B 722, respectively.

The heartbeat transmitters A 712 and B 722 issue
heartbeat commands at an interval of a certain period of

10   time to the heartbeat receivers A 512 and B 522, which are
components of the enclosure service units A 51 and B 52,
respectively. The heartbeat receivers A 512 and B 522
which are components of the enclosure service units A 51
and B 52, as aforementioned, receive the issued heartbeat

15   commands. The heartbeat monitors A 511 and B 521 monitor
reception status of the heartbeat commands and when detect
that heartbeat commands have ceased in both heartbeat
receivers A 512 and B 522, all FC-AL disks 21 to 2N are
detached from both FC-ALs A 41 and B 42. The period of

20   time, by which the heartbeat monitors A 511 and B 522
determine that the receptions of the heartbeat commands
have ceased, may be set by the disk controllers A 71 and B
72. The heartbeat transmitters A 712 and B 722 issue
commands to the heartbeat receivers A 512 and B 522 at an

25   interval shorter than the period for determining that the

commands receptions cease.

The loop diagnostic units A 711 and B 721 have functions of, when loop abnormalities occur, performing loop diagnoses including bypass and release the bypass of

5   the FC-AL disks in cooperation with each other.

The temporary degeneracy controllers A 710 and B 720 have functions of controlling cooperation between the host controllers A 81 and B 82 and the disk controllers A 710 and B 720 in order to continue responding to the hosts A 91

10   and B 92 during loop diagnoses.

Fig. 3 shows an example of the inner structure of the disk controller A 71. Since the disk controller B 72 has the same structure, Fig. 3 only shows the disk controller A 71. The disk controller A 71 shown in Fig. 3 comprises a

15   computer, which includes a CPU 731, an interface chip 733 connecting a bus 732 of the CPU 731, a memory 734, a communication unit 735, and a data transfer unit 736 including a DMA (dynamic memory access) controller and the like. The interface chip 733 is a portion of the interface

20   between the disk controller A 71 and the FC-AL A 41. A loop abnormality detecting mechanism in the disk controller A 71 is typically provided in the interface chip 733. The communication unit 735 is a device for communicating each other with other controllers via a communicating means

25   between controllers 100. The data transfer unit 736 is a

device for exchanging data with other controllers through

an inner bus 110, as well as exchanging data with the

enclosure service unit A 51 and each of the disks 21 to 2N

through the interface chip 733 and the FC-AL A 41. The

5   memory 734 including ROM and RAM stores programs for

letting a computer as the disk controller execute the

aforementioned function of the disk controller (including

firmware). The CPU 731 executes programs for the disk

controller stored in the memory 734 to thereby control the

10   whole disk controller and realize functions necessary for

the disk controller.

(Operation)

Next, the operation of the disk array apparatus

15   according to the present embodiment will be explained.

Referring to Fig. 1, the host controllers A 81 and B

82 which received instructions from the hosts A 91 and B 92

recognize such necessary information as logic disk numbers

(LUN), instruction code types, and logic block addresses

20   (LBA). For example, the host controller A 81 and B 82

which received read instructions from the hosts A 91 and B

92, immediately transfer data from the cash unit 6 to the

host A 91 and B 92, if the designated data exists in the

cash unit 6. If the designated data does not exist in the

25   cash unit 6, the host controllers A 91 and B 92 instruct

the disk controllers A 71 and B 72 to store data read out

from the FC-AL disks 21 to 2N in the cash unit 6, and when

the data is stored in the cash unit 6, transfer the data to

the host A 91 and B 92. Further, if the host controllers A

5   81 and B 82 received write instructions from the host A 91

and B 92, for example, they store the data received from

the hosts A 91 and B 92 in the data in the cash unit 6.

This data is written in the FC-AL disks 21 to 2N by the

disk controllers A 71 and B 72, through instructions from

10   the host controllers A 81 and B 82 to the disk controllers

A 71 and B 72 to write the data into the disks, or through

detection by the disk controllers A 71 and B 72 that

unwritten data exists in the cash unit 6. Generally, the

two disk controllers A 71 and B 72 are used to share the

15   FC-AL disks 21 to 2N to which processing is assigned, so as

to divide the loads.

Next, a process, when loop abnormalities occur in the

FC-AL A 41 and the FC-AL B 42, will be explained.

When a loop abnormality occurs only in the FC-AL A 41,

20   signals cannot propagate on the FC-AL A 41. Therefore, the

disk controller A 71 detects the state as same as

conventional examples. At this time, the heartbeat

commands, which are regularly transmitted by the heartbeat

transmitter A 712 in the disk controller A 71, have not

25   been received in the heartbeat receiver A 512 any more, so

that the heartbeat monitor A 511 detects that a loop

abnormality occurs in the FC-AL A 41. In this case, since

the other FC-AL B 42 is in the normal state, a control for

bypassing disks 21 to 2N from the FC-AL A 41 is not

5   performed.

In contrast, when a loop abnormality occurs only in

the FC-AL B 42, signals cannot propagate on the FC-AL B 42.

Therefore, the disk controller B 72 detects the state as

same as conventional examples. At this time, the heartbeat

10 commands, which are regularly transmitted by the heartbeat

transmitter B 722 in the disk controller B 72, have not

been received in the heartbeat receiver B 522 any more, so

that the heartbeat monitor B 521 detects that a loop

abnormality occurs in the FC-AL B 42. In this case, since

15 the other FC-AL A 41 is in the normal state, a control for

bypassing disks 21 to 2N from the FC-AL B 42 is not

performed.

When loop abnormalities occur in both FC-Als A 41 and

B 42, the disk controller A 71 detects the loop abnormality

20 in the FC-AL A41, and the disk controller B 72 detects the

abnormality in the FC-AL B 42. Further, the heartbeat

monitors A 511 and B 521 in the enclosure service units A

51 and B 52 detect that loop abnormalities occur in both

FC-Als A 41 and B 42. Then, according to an instruction

25 from the loop connection controller A 513, the loop

connection switching unit A 31 is controlled, so that all

disks 21 to 2N are bypassed from the FC-AL A 41. At the

same time, the loop connection switching unit B 32 is

controlled according to an instruction from the loop

5   connection controller B 523, so that all disks 21 to 2N are

bypassed from the FC-AL B 42.

Fig. 4 is a flowchart showing a processing example

when the disk controllers A 71 and B 72 detect loop

abnormalities in their own loops. Since the disk

10 controllers A 71 and B 72 perform the same processing, only

the disk controller A 71 will be explained below as an

example. The function of the disk controller shown in Fig.

4 is formed as a program for letting the computer, which

acts as the disk controller, execute. The function of the

15 disk controller is performed by letting the computer

execute this program.

The disk controller A 71, when detects a loop

abnormality in the FC-AL A 41 (S101), inquires the disk

controller B 72 about the loop status of another FC-AL B 42

20 via the communicating means between controllers 100 (S102).

Responding to the inquiry, the disk controller B 72 replies

to the disk controller A 71 whether the loop status of the

FC-AL B 42 is normal or abnormal via the communicating

means between controllers 100. If the FC-AL B 42 is not in

25 the abnormal state but in the normal state (NO in S103),

the disk controller A 71 performs countermeasure processing

against a single-route link failure, which is the process

for a case that a loop abnormality occurs in only one loop.

The details of the countermeasure processing against a

5   single-route link failure will be explained later. On the

other hand, if a loop abnormality occurs in the FC-AL B 42

as well (YES in S103), the disk controller A 71 proceeds to

the step S105.

In the step S105, the disk controller A 71 waits for

10   a certain period of time. The waiting period is a little

longer than a period necessary for the enclosure service

units A 51 and B 52 to voluntarily bypass the disks 21 to

2N from the FC-Als A 41 and B 42 when the loop

abnormalities occur in both FC-Als A 41 and B 42. When the

15   waiting period passed, the disk controller A 71 judges

whether the loop abnormality of the FC-AL A 41 is resolved

(S106). If the abnormality of the own loop is resolved

(YES in S106), the disk controller A 71 inquires the

enclosure service unit A 51 that whether all disks 21 to 2N

20   were bypassed since receptions of the heartbeat commands

ceased in both loops, through the FC-AL A 41 in which the

loop abnormality is resolved (S107). Responding to the

inquiry, if the enclosure service unit A 51 replies that it

bypassed all disks (YES in S108), the disk controller A 71

25   performs countermeasure processing against a double-routes

link failure, which is a process performed when loop

abnormalities occur in both FC-Als A 41 and B 42 (S109).

The details of the countermeasure processing against a

double-route link failure will be described later.

5   On the other hand, when the enclosure service unit A

51 replies that no bypass of all disks was performed (NO in

S108), the disk controller A 71 proceeds on the

understanding that the loop abnormality was an intermission

failure and was naturally cured. For a case that the disk

10   controller A 71 waited for a certain period of time in the

step S105 but the loop abnormality in the FC-AL A 41 was

not resolved (NO in S106), the cause of the loop

abnormality exits in devices other than the disks 21 to 2N,

for example a failure of the enclosure service unit A 51

15   itself. Therefore, the disk controller A 71 performs

countermeasure processing against failure corresponding to

the cause. Since the countermeasure processing against

failure is not directly related to the present invention,

the explanation is omitted.

20   In the example of processing in Fig. 4, when the

other loop is also in the abnormal state (YES in S103), the

disk controller A 71 waits for a certain period of time

(S105) and then judges whether the abnormal state of the

own loop is resolved (S106). However, this part of

25 processing may be changed to that shown in Fig. 5. That is,

when the other loop is also in the abnormal state (YES in

S103), the disk controller performs processing including

the process of S106 for judging whether the abnormal state

of the own loop has been resolved and the process of S110

5   for judging whether a certain period of time has passed.

If the abnormal state of the own loop has been resolved,

the disk controller A 71 proceeds to the step S107, and if

the abnormality of the own loop has not been resolved

although a certain period of time passed (YES in S110),

10   proceeds to other countermeasure processing against failure.

In Fig. 4, it is necessary to wait for a certain period of

time even though the loop failure was an intermission

failure and was resolved immediately. However, the process

shown in Fig. 5 has an advantage that such a waiting period

15   is not needed.

Next, the countermeasure processing against a single-

route link failure in the step S104 will be explained with

an example that a loop abnormality occurs in the FC-AL A 41.

Of course, the same operation is performed in the case of

20   the FC-AL B 42.

Fig. 6 is a flowchart showing an example of the

countermeasure processing against a single-route failure

(S104). This processing is formed as a program. By

letting the computer execute this program, the processing

25   shown in Fig. 6 is performed. As an example, assuming that

a loop abnormality such as link down continues in the FC-AL

A 41 caused by a fault in any one of the FC-AL disks 21 to

2N (S1041). In this state, the disk controller A 71 cannot

access to the enclosure service unit A 51 and the FC-AL

5   disks 21 to 2N. The temporary degeneracy unit A 710 in the

disk controller A 71 stops executing the normal disk

processing (S1042) (the state in which the normal function

stops is called a temporary degeneracy state), and informs

the host controllers A 81 and B 82, and the other disk

10   controller B 72 that the state is transited to the

temporary degeneracy state (temporary degeneracy

information) (S1043).

The disk controller B 72 and the host controllers A

81 and B 82, upon receipt of the temporary degeneracy

15   information, operate the system in the temporary degenerate

state of the loop A (S1044). More specifically, the

temporary degeneracy controller B 720 in the disk

controller B 72, which received the temporary degeneracy

information, first resets the FC-AL disks 21 to 2N, and

20   cancels remaining processes in the FC-AL disks 21 to 2N

caused by abandonment of disk processing by the regenerated

disk controller A 71. Further, the disk controller B 72

performs disk processing instructed by the host controllers

A 81 and B 82, and disk processing determined by itself,

25   for all of the FC-AL disks 21 to 2N. On the other hand,

the host controllers A 81 and B 82, upon receipt of the temporary degeneracy information, request to the substitute disk controller B 72 to perform uncompleted disk processing which has been requested to the degenerated disk controller

5   A 71. Further, during the time that the disk controller A 71 is temporary degenerated, every disk processing by the new host I/O is requested to the substitute disk controller B 72. Accordingly, since the disk controller B 72 succeeds processing during the time of the disk controller A 71

10 being degenerated, it is possible to continue responding to the hosts.

Next, the loop diagnostic unit A 711 in the disk controller A 71 which is temporary degenerated and the loop diagnostic unit B 721 in the disk controller B 72 cooperate

15 each other to perform diagnostic processing for identifying a faulty component of the disks 21 to 2N connected to the FC-AL A 41 (S1045). A specific example of the loop diagnostic processing of the step S1045 will be described below.

20 First, the loop diagnostic unit A 711 in the disk controller A 71 instructs, via the communicating means between controllers 100, the loop diagnostic unit B 721 in the disk controller B 72 to bypass, for example, the disk 21 among the FC-AL disks 21 to 2N. The disk controller B

25 72, upon receipt of the instruction, instructs the

enclosure service unit B 52 of the same bypass, through the FC-AL B 42, and the enclosure service unit B 52 instructs the enclosure service unit A 51 of the same bypass, through the interface 130. The loop connection controller A 513 in

5 the enclosure service unit A 51, upon receipt of the instruction, controls the loop connection switching unit A 31 so as to detach the disk 21 from the FC-AL A 41. The disk controller A 71 judges whether the loop abnormality in the FC-AL A 41 has been resolved, and if resolved,

10 identifies the disk 21 as the faulty disk. On the other hand, if the loop abnormality still continues, the next disk 22 is bypassed from the FC-AL A 41 with the same procedure as that of the disk 21, and checked whether the disk 22 is the faulty disk or not. This process is

15 repeated through the last disk 2N until the faulty disk is identified.

When the faulty disk is identified through this process, the disk controller A 71 detaches the faulty disk and releases the normal disks from bypass so as to

20 reconnects them to the FC-AL A 41 (step S1046). For example, in a case that the disk 22 is the faulty disk, only the faulty disk 22 is detached from the FC-AL A 41 and the normal disks are connected to the FC-AL A 41, as shown in Fig. 7.

25 Subsequently, the disk controller A 71 informs, via

the communicating means b tween controller 100, the host

controllers A 81 and B 82 and the other disk controller B

72 that the temporary degenerate state has been cleared and

transited to the normal state (temporary degeneracy cleared

5   information) (S1047). The disk controller A 71, which

cleared the temporary degenerate state, resumes disk

processing of the normal function. The disk controller B

72, when received the temporary degeneracy cleared

information, stops processing of the disks handled by the

10   disk controller A 71 in which the temporary degenerate

state was cleared, and takes charge of processing the

remaining disks including the disk bypassed from the other

loop through the loop diagnosis. The host controllers A 81

and B 82, upon receipt of the temporary degenerate cleared

15   information, request disk processing to the disk

controllers A 71 and B 72 corresponding to the

aforementioned handling of the disks. As for the disk

determined as faulty, it is informed to the maintenance

staff or users that the disk is required to be replaced, by

20   a maintenance terminal (not shown) connecting to the disk

array apparatus 1 or a host (not shown) for managing the

disk array connected through a host path or the like.

The specific example of the loop diagnostic

processing described above is just an example and the

25   present invention is not limited to the aforementioned

example. For example, a loop diagnosis may be performed

with the procedure shown in Fig. 5 of the aforementioned

second conventional example, that is, the Japanese Patent

Laid-open No. 2001-216206. Further, it may be performed in

5   such a manner that all disks 21 to 2N connecting to the FC-

AL A 41 are bypassed for a while and releasing them one by

one so as to check each disk for a failure.

Next, the countermeasure processing against a double-route

link failure (S109) shown in Fig. 4 will be explained.

10   Fig. 8 is a flowchart showing an example of the

countermeasure processing against a double-system link

failure S109. This processing is formed as a program. By

letting the computer execute this program, the processing

shown in Fig. 8 is performed. Before starting the

15   countermeasure processing against a double-route link

failure, all disks 21 to 2N are bypassed from the FC-AL A

41 and B 42 by the enclosure service units A 51 and B 52.

In this state, both disk controllers A 71 and B 72 cannot

perform normal disk processing. Therefore, the temporary

20   degeneracy controllers A 710 and B 720 in the disk

controllers A 71 and B 72 stop normal disk processing and

let the state to be a temporary degenerate state (S1091),

and inform the host controllers A 81 and B 82 that the

state transited to the temporary degenerate state

25   (temporary degeneracy information) (S1092), via the

communicating means between controllers 100. The host controllers A 81 and B 82, upon receipt of the temporary degeneracy information, suspend to receive requests form the hosts A 91 and B 92, since all disk controllers A 71

5   and B 72 are in the temporary degenerate state (S1093).

Next, the loop diagnostic units A 711 and B 721 in the disk controllers A 71 and B 72 first cooperatively perform diagnostic processing for identifying a faulty component among a plurality of disks 21 to 2N connecting to

10 either one of FC-ALs, for example, the FC-AL A 41 (S1094). A specific example of the loop diagnostic processing of the step S1094 will be explained below.

First, the loop diagnostic unit A 711 in the disk controller A 71 instructs, via the communicating means

15 between controllers 100, the loop diagnostic unit B 721 in the disk controller B 72 to connect (release the bypass of) a disk among the FC-AL disks 21 to 2N, for example, the disk 21 to the FC-AL A41. The disk controller B 72, upon receipt of the instruction, instructs through the FC-AL B

20 42 the enclosure service unit B 52 to release the bypass as well, and the enclosure service unit B 52 instructs the enclosure service unit A 51 to release the bypass as well through the interface 130.

The loop connection controller A 513 of the enclosure

25 service unit A 51, upon receipt of the instruction,

controls the loop connection switching unit A 31 to connect

the disk 21 to the FC-AL A 41. The disk controller A 71

judges whether the loop abnormality of the FC-AL A 41

occurs again, and if so, identifies the disk 21 as the

5   faulty disk. If the loop abnormality does not occur again,

the disk 21 is identified as a normal disk.

In a case that the disk 21 is identified as a faulty

disk, the loop diagnostic unit A 711 of the disk controller

A 71 instructs the enclosure service unit A 51 to bypass

10   the disk 21, through the same channel as used in

instructing the release of the bypass, that is, a channel

via the communicating means between controllers 100, the

loop diagnostic unit B 721, the enclosure service unit B 52,

and the interface 130. Then, after detaching the faulty

15   disk 21 from the FC-AL A 41, the loop diagnostic unit A 711

performs a diagnosis of the disk 22 as same as that of the

disk 21.

In a case that the disk 21 is not the faulty disk,

the loop diagnostic unit A 711 performs a diagnosis of the

20   disk 22 as same as that of the disk 21 while the disk 21

connects to the FC-AL A 41. This procedure is repeated for

all remaining disks. When the loop diagnosis of the FC-AL

A 41 completed, only the normal disks connect to the FC-AL

A 41.

25   The above explanation illustrates a case that when

the disk controller A 71 connects the disks 21 to 2N to the

FC-AL A 41, the instruction to release the bypass is

transmitted through the other disk controller B 72, the FC-

AL B 42, and the enclosure service unit B 52. However, the

5   instruction to release the bypass may be directly

transmitted to the enclosure service unit A 51 through the

FC-AL A 41. It should be noted that if a disk, released

from the bypass, is the faulty disk, the loop abnormality

occurs again in the FC-AL A 41. Therefore, when detaching

10   the disk again, it is required to transmit the instruction

of the bypass to the enclosure service unit A 51 via the

other disk controller B 72, the FC-AL B 42, and the

enclosure service unit B 52.

Subsequently, the disk controller A 71 informs the

15   host controllers A 81 and B 82, by the communicating means

between controllers 100, that the temporary degenerate

state of the loop A is cleared and transited to the normal

state (temporary degenerate cleared information) (S1095).

With this information, the operation of the system resumes

20   in the temporary degenerate state of the loop B (S1096).

The host controllers A 81 and B 82, which received the

temporary degenerate cleared information of the loop A,

request the disk controller A 71, in which the temporary

degenerate state is cleared, to perform the uncompleted

25   disk processing again which has been requested to the disk

controllers A 71 and B 72 which are temporary degenerated. Further, the host controllers A 81 and B 82 resume accepting requests from the hosts A 91 and B 92, and request the disk controller A 71 to perform every disk

5   processing by the new host I/O. The disk controller A 71 cancels disk processing remaining in the all normal FC-AL disks, and then performs disk processing instructed by the host controllers A 91 and B 92 and disk processing determined by the disk controller A 71, for the all normal

10 FC-AL disks. With this process, it is possible to minimize the period in which the system operation completely stops.

Next, the loop diagnostic unit A 711 in the disk controller A 71 which cleared the temporary degeneracy and the loop diagnostic unit B 721 in the disk controller B 72

15 which is temporary degenerated, cooperatively perform diagnostic processing to identify a faulty component among the disks 21 to 2N connecting to the FC-AL B 42 (S1097). The loop diagnostic processing of the step S1097 is performed as follows, as same as the processing of the step

20 S1094.

First, the loop diagnostic unit B 721 of the disk controller B 72 instructs the enclosure service unit B 52 to connect (release the bypass of) a disk, for example, the disk 21, among the FC-AL disks 21 to 2N via the

25 communicating means between controllers 100, the loop

diagnostic unit 711 in the disk controller A 71, the FC-AL A 41, the enclosure service unit A 51, and the interface 130. The loop connection controller B 523 in the enclosure service unit B 52, upon receipt of the instruction,

5 controls the loop connection switching unit B 32 so as to connect the disk 21 to the FC-AL B 42. The disk controller B 72 judges whether the loop abnormality occurs in the FC-AL B 42 again, and if so, identifies the disk 21 as a faulty disk. If the loop abnormality does not occur again,

10 the disk 21 is identified as a normal disk. In the case that the disk 21 is identified as a faulty disk, the loop diagnostic unit B 721 of the disk controller B 72 instructs the loop connection switching unit B 32 to bypass the disk 21, through the same channel as used in instructing the

15 release of the bypass. Then, after detaching the faulty disk 21 from the FC-AL B 42, the loop diagnosis unit B 52 performs diagnosis of the disk 22 as same as that of the disk 21.

In the case that the disk 21 is not the faulty disk,

20 the loop diagnostic unit B 52 performs a diagnosis of the disk 22 as same as that of the disk 21 while the disk 21 connects to the FC-AL B 42. This procedure is repeated for all remaining disks. When the loop diagnosis of the FC-AL B 42 completed, only the normal disks connect to the FC-AL

25 B 42. Same as the case of the step S1094, the disk

controller B 72 may transmit the instruction of releasing

the bypass directly to the enclosure service unit B 52

through the FC-AL B 42.

Subsequently, the disk controller B 72 informs, by

5   the communicating means between controllers 100, the host

controllers A 81 and B 82 and the other disk controller A

71 that the temporary degenerate state of the loop B has

been cleared and transited to the normal state (temporary

degenerate cleared information) (S1098). With this process,

10   the operation of the system continues using both loops A

and B (S1099). That is, the disk controller B 72 which

cleared the temporary degenerate state resumes disk

processing of the normal function. The disk controller A

71, upon receipt of the temporary degenerate cleared

15   information, stops processing of disks of which the disk

controller B 72 cleared the temporary degenerate takes

charge. The host controllers A 81 and B 82, upon receipt

of the temporary degenerate cleared information of the loop

B, request disk processing to the disk controllers A 71 and

20   B 72 corresponding to their responsibilities to the

aforementioned disks. It should be noted that as for the

disk determined as faulty, it is informed to the

maintenance staff or the users by a maintenance terminal

(not shown) connecting to the disk array apparatus 1 or a

25   host for managing the disk array connecting via a host path

that the disk is required to be replaced.

The aforementioned specific example of the loop
diagnosis described in the steps S1094 and S1097 is just an
example, and the present invention is not limited to this

5   specific example. As an example of the diagnostic method
in the step S1094, it is acceptable to connect a plurality
of disks at the same time. That is, connecting a half
number of disks to the FC-AL A 41 at the same time and if a
loop abnormality does not occur, connecting the remaining

10   half number of disks to the FC-AL A 41 at the same time.
In this case, if a loop abnormality occurs when connecting
a plurality of disks, it means that a faulty disk exists in
those disks. Therefore, the process of identifying the
faulty disk may be performed to the disks. The same loop

15   diagnostic method can be used in the step S1097.

Practically, there are many cases that abnormalities
occur in the both loops because of a failure of one disk.
Therefore, in the step S1097, it is acceptable to check
whether the loop abnormality occurs again by connecting all

20   disks other than the disk determined as faulty to the FC-AL
B 42, considering the result of the step S1094. However,
there is a case, though it is rare, that one loop in each
of the two disks fails at the same time so that two loop
abnormalities occur. In this case, the loop abnormality

25   occurs again. Therefore, the diagnosis should be continued

so as to identify another faulty disk causing the loop

abnormality in the FC-AL B 42.

(Other embodiments)

5   In the aforementioned embodiment, when the heartbeat

monitors A 511 and B 521 in the enclosure service units A

51 and B 52 detect both loop abnormalities, all disks 21 to

2N are detached from the FC-AL A 41 and from the FC-AL B 42

by the loop connection controllers A 513 and B 523, so as

10   to resolve both loop abnormalities. However, the present

invention is not limited to the aforementioned embodiments.

In the present invention, it is acceptable that all disks

21 to 2N are detached from one FC-AL, for example, the FC-

AL B 42, but are connected to the other FC-AL A 41. In

15   this case, a loop abnormality in the FC-AL B 42 is resolved

but a loop abnormality in the FC-AL A 41 is not resolved.

This state is quite similar to that of a loop abnormality

which occurs only in one loop. In this case, a loop

diagnosis to identify a faulty disk among the disks

20   connected to the FC-AL A 41 can be performed by accessing

from the disk controller A 71 to the enclosure service unit

A 51 through the FC-AL B 42 having no loop abnormality,

with the same method described in the step S1045. Then,

detaching the disk determined as faulty in the loop

25   diagnosis, the loop abnormality in the FC-AL A 41 can be

resolved. Then, a loop diagnosis of the other FC-AL B 42

can be performed by the same method as that of the step

S1045.

In the aforementioned embodiment, the present

5   invention is applied to the disk array apparatus in which

one FC-AL connects to each of the disk controllers A 71 and

B 72. However, the present invention is not limited to this

structure. The present invention may be applied to a disk

array apparatus in which a plurality of FC-ALs connect to

10 each of the disk controllers A 71 and B 72, an example of

which is shown in Fig. 9.

A disk array apparatus shown in Fig. 9 includes two

disk unit devices, or a disk unit device 5 and the similar

disk unit device 5X. FC-ALs A 41 of the both disk unit

15 devices connect to a disk controller A 71, and FC-ALs B 42

of the both disk unit devices connect to a disk controller

B 72. That is to say, two independent disk unit devices 5

and 5X connect to the disk controllers A 71 and B 72 in

parallel. In the disk array apparatus shown in Fig. 1

20 which only includes the disk unit 5, disk array is formed

by using the disks in the disk unit 5. However, the disk

array apparatus shown in Fig. 9 can form the disk array by

combining disks in the different disk unit device in

addition to the disk array shown in Fig. 1. For example, a

25 disk 21 in the disk unit device 5 and a disk 21 in the disk

unit device 5X can form a disk array of RAID1. In this

case, even when dual loop abnormalities occur in either one

of the disk unit devices, disk processing can be continued

in the other disk unit device, so that the reliability is

5   improved. Note here that when dual loop abnormalities

occur in each of the disk unit devices 5 and 5X, processing

is basically the same as that of the disk array apparatus

shown in Fig. 1.

In the aforementioned embodiments, the present

10   invention is applied to a disk array apparatus in which one

enclosure service unit connects to one FC-AL. However, the

present invention is not limited to this structure, and it

is applicable to a disk array apparatus in which a

plurality of enclosure service units connect to one FC-AL.

15   An example of which is shown in Fig. 10.

In a disk array apparatus shown in Fig. 10, the

number of disks connecting to each of the FC-ALs A 41 and B

42 is extended by a disk unit device 5Y (extension

apparatus) which is similar to the disk unit device 5. In

20   this case, each of the basic apparatus having the disk unit

device 5 and the extension apparatus having the disk unit

device 5Y has one enclosure service unit per one loop,

respectively. Therefore, enclosure service units 51 and 52

arranged in respective loops in the disk unit device 5 are

25   connected by an interface 130 so as to communicate each

other, and enclosure service units 51 and 52 arranged in the respective loops in the disk unit device 5Y are also connected by an interface 130 so as to communicate each other. Further, heartbeat commands from disk controllers A

5 71 and B 72 are transmitted to all enclosure service units connected to the same loop. Each enclosure service unit, when detecting loop abnormalities in the both loop, detaches all disks connecting to the basic apparatus or the extension apparatus, in which the enclosure service unit

10 itself is provided.

Embodiments of the present invention have been explained above. However, the present invention is not limited to the aforementioned embodiments and is possible to accommodate other various additions and modifications.

15 For example, although the enclosure service unit detects a loop abnormality by recognizing that reception of heartbeat commands ceased, it is acceptable that the same function as the loop abnormality detecting function in the disk controller may be provided in the enclosure service unit.

20 Further, the aforementioned program is recorded on a computer-readable storage medium and traded.

As described above, the present invention has the following effects.

In a system including, controlling devices such as

25 enclosure service devices for controlling loop connection

switching means which perform connecting/detaching of

devices to/from loops, and multiplied loop interfaces to

which the controlling devices directly connect, it is

possible to perform detaching and reconnecting devices even

5   though loop abnormalities occur at the same time in all of

the loop interfaces. The reason is as follow. When

abnormalities occur in all of the multiplied loop

interfaces, they are detected by the controlling devices.

The controlling devices voluntarily control the loop

10   connection switching means so as to detach all devices

connected to at least one loop interface from the loop, to

thereby resolve at least one loop abnormality in one loop

interface. Accordingly, it is possible to access to the

controlling devices connected to the loop, and via the

15   controlling devices, it is also possible to access to

controlling devices connected to other loops.

In a system including, controlling devices such as

enclosure service devices for controlling loop connection

switching means which perform connecting/detaching of

20   devices to/from loops, and multiplied loop interfaces to

which the controlling devices directly connect, it is

possible to perform loop diagnoses for identifying faulty

devices causing the loop abnormalities even when loop

abnormalities occur at the same time in all of the loop

25   interfaces. The reason is as follows. In order to perform

loop diagnoses, it is required to detach and reconnect the devices connecting to the loop interfaces, which can be performed in the present invention.

In a system including, controlling devices such as
5   enclosure service devices for controlling loop connection switching means which perform connecting/detaching of devices to/from loops, and multiplied loop interfaces to which the controlling devices directly connect, it is possible to prevent the system from being completely
10 stopped even when loop abnormalities occur at the same time in all of the loop interfaces. The reason is that the loop diagnoses can be performed as aforementioned, so that the faulty components can be removed from the loops and the operation of the system can be resumed.